Winter roost habitat use by Eurasian Marsh Harriers *Circus aeruginosus* in and around Keoladeo National Park, Bharatpur, Rajasthan, India

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Roosts of Eurasian Marsh Harriers *Circus aeruginosus* were studied for four winters between 1996 and 2000 in and around Keoladeo National Park (KNP), eastern Rajasthan, India. Fourteen communal roosts were found, in which harriers gathered in loose aggregations of 11–132 birds. Roosts were situated in tall grasses and wetlands with floating vegetation in KNP, and in tall grasses, sedges, crops and bare ground in areas adjoining KNP. Birds shifted to roosts in wetlands and peripheral sites when grassland roosts in KNP were disturbed during the grass-cutting season. A comparison of roost sites with randomly selected non-roost sites in grassland indicated that birds preferred sites in tall grasses and further from the nearest trees and road.

INTRODUCTION

Studies of ecology and behaviour in both wintering (e.g. Newton 1979) and breeding grounds (e.g. Doody 1994) are essential to understand a bird's complete life cycle and to formulate effective conservation strategies. However, for raptors in general, and for harriers in particular, far fewer studies have been conducted at wintering grounds than at breeding grounds. This imbalance is very apparent for the Eurasian Marsh Harrier *Circus aeruginosus* (Cramp and Simmons 1980). Here, we present the first detailed study of Eurasian Marsh Harrier wintering ecology in India.

The few previous studies of harriers in India consist mainly of casual observations (Donald 1905, Abdulali 1958, Navarro 1962, Khacher 1978, Rahmani and Manakadan 1987, Prakash 1988, Rahmani 1988, Satheesan and Rao 1990, Narayan and Rosalind 1991, Vyas 1992, Clarke 1996, Akhtar 1998, and Ganesh and Kanniah 2000). Verma (2002) studied this species at a roost in Keoladeo National Park during 1996–2000, counting 48–132 individuals, with numbers peaking in November and immatures outnumbering adults. Akhtar (1998) studied a harrier roost at Velavadar National Park, Gujarat, and found that this species was outnumbered by Montagu's *Circus pygargus* and Pallid Harriers *C. macrourus*.

In the present study, we aimed to: (1) identify winter roost habitats of the Eurasian Marsh Harrier within a 25-km radius of Keoladeo National Park; (2) study roost-site selection; and (3) investigate disturbance factors.

METHODS

Study site

The study was carried out in August–April each year during 1996–2000 in Keoladeo National Park (KNP), eastern Rajasthan, India (27°8–12′N 77°30–34′E; Fig. 1). KNP is located 180 km south of Delhi, at c.174 m, and covers c.29 km^2. The area lies in the Punjab Plains biotic province of the semi-arid biogeographical zone (Rodgers and Panwar 1988), which is a flat, dry area of the Indus-Yamuna watershed.

Habitat types in KNP include forest, woodland, scrub-woodland, scattered shrubs, savanna-woodland, shrub-savanna, grass-savanna and grassland with scattered trees and shrubs (Perennou and Ramesh 1987). The grasslands are formed mainly by *Vetiveria zizanioides* and *Desmostachya bipinnata* with trees and shrubs consisting of *Prosopis cineraria*, *Acacia nilotica*, *A. leucophloea*, *Ziziphus mauritiana* and *Salvadora persica*. The grasslands lie in the south-east corner of KNP in block G (Fig. 1) and are about 3 km^2 in area.

The central part of KNP is wetland, dominated by the perennial grass *Paspalum distichum*. The wetland is fed partly by rains and partly from a temporary reservoir (Ajan Dam) situated 0.5 km south of the park (Fig. 1). The reservoir is usually dry from early October until next monsoon in June–July, during which time the villagers use it for cultivation. There are 18 villages around KNP, which grow 'bajra' *Pennisetum typhoides*, 'dencha' (a fodder crop) *Sesbania bispinosa*, wheat *Triticum aestivum*, mustard *Brassica campestris*, rice *Oryza sativa* and pulses.

Summer (March–May) in KNP is characterised by hot, dry weather, dust storms, low humidity and monthly rainfall of only a few millimetres. Winter (November–February) is cold, with chilly winds and fog. Temperatures during 1996–2000 ranged from 3.7°C in December 1996 to 48.5°C in May 1998 (*per* Meteorological Department, Bharatpur). KNP receives most of its precipitation from the south-west monsoon, from the end of June to September. During the study period the average annual rainfall was 788 mm.

Data collection

Communal harrier roosts were located by following harriers at their foraging grounds from an hour before sunset until they roosted. Radio-telemetry was also used to locate roosts around KNP. Four harriers (three juveniles and one adult female) were radio-tagged and tracked during December 1999–February 2000 using a three-element, hand-held Yagi antenna with a receiver.

Each week, we counted the number of harriers present at each communal roost, using binoculars (8×35) and a telescope (20×) from c.100–250 m away. At each communal roost we recorded the habitat, vegetation composition, mean height of vegetation, area and the distance from the centre of the roost to the nearest road, tree and water body. The total roost area was defined as the area encompassing the locations of all pre-roosting birds. To examine selection of roosting habitat in grasslands, we randomly selected a 150×150 m area within each of five grassland communal roosts, and compared the characteristics of these areas with those in five randomly

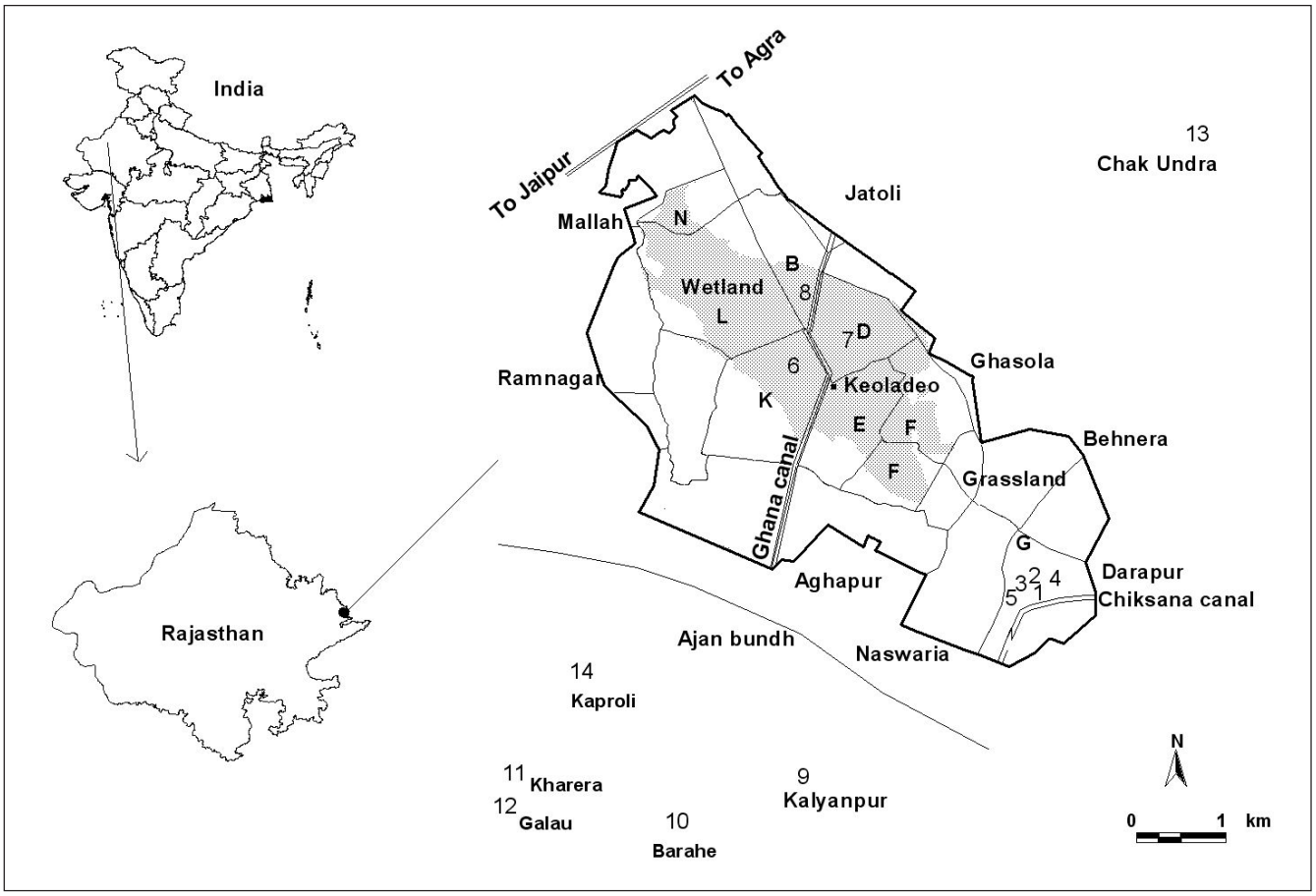

Figure 1. Map of Keoladeo National Park. The shaded portion in the centre indicates wetland areas used by wintering harriers for foraging (and, occasionally, roosting). Numbers indicate communal harrier roosts and correspond to those listed in Table 1.

selected non-roost areas measuring 150×150 m. In each roost and non-roost site, we recorded the average percentage cover and height of *Vetiveria zizanioides* and *Desmostachya bipinnata* grasses, the distance to the nearest tree, road and water body, and the number of trees.

Data on individual roost sites within the communal roost were collected the next morning after the harriers had left. In total, we studied 525 individual roost sites (396 in grasslands, 54 in wetlands, 34 in crop fields, 25 in sedge fields and 16 in ploughed fields), which were identified from the presence of pellets, downy feathers and excreta. For each roost site, we recorded the vegetation composition, percentage cover of each plant species, vegetation height, and the distance to the next nearest roost site. Means ± SD are presented throughout.

RESULTS

Communal roosts

A total of 14 communal harrier roosts were located; eight in KNP and six in adjoining areas within a radius of 25 km (Table 1, Fig. 1). They were situated in a variety of habitats, with grasslands being the most frequent (43% of roosts), followed by wetlands (21%), crop fields (21%), sedge fields (7%) and ploughed fields (7%). We compared vegetation parameters for communal roosts in grassland with randomly selected non-roost sites in grassland. The only significant difference was that roost sites had a higher percentage cover of *Vetiveria zizanioides*, although sample sizes were low (Table 2). The maximum number of harriers recorded at grassland communal roosts over the four years was significantly positively correlated with the distance to the nearest tree (Table 3).

Individual roost sites

Of 525 individual roost sites studied in various roost habitats, 57% were located in a mix of *Vetiveria zizanioides* and *Desmostachya bipinnata* grasses, 11% in *Desmostachya bipinnata* alone, 7% in *Vetiveria zizanioides* alone, 8% in *Eichhornia crassipes*, and the remainder in *Triticum aestivum*, *Scirpus tuberosus*, *Paspalum distichum*, *Cyperus alopecuroides*, *Sesbania* or bare ground. For sites in mixed *Vetiveria zizanioides* and *Desmostachya bipinnata* grasses, the former generally remained standing as protective cover while the latter was flattened to form the roosting platform. In grassland roosts, the majority (73%) of roost sites appeared to be formed by trampling of vegetation by the harriers themselves, 24% had been previously flattened by resting ungulates (mostly spotted deer *Axis axis* and nilgai *Boselaphus tragocamelus*), and 3% were natural depressions. Individual roost sites averaged 1.1±0.8×0.7±0.6 m. The mean distance to the next nearest roost site was 2.4±1.7 m (range 0.5–10.0 m).

Of 54 individual roost sites in wetlands, 74% were located on water hyacinth *Eichhornia crassipes* (an exotic weed), occasionally interspersed with *Paspalum distichum*, *Panicum* spp. and *Pseudoraphis spinescens*, in water that averaged 50±13 cm deep. In sedge fields, tall (1–1.5 m) stands of *Scirpus tuberosus* and *Desmostachya bipinnata*

Table 1. Communal harrier roosts located in and around Keoladeo National Park during 1999–2000. Numbers correspond to those in Fig. 1.

No.	Location	Season used	Total roost area (km²)	Max. no. recorded (years)	Habitat	Principal vegetation	Vegetation height (m)	Distance to nearest road (m)	Distance to nearest tree (m)	Distance to nearest water body (km)
1	South-east KNP (G-1) 27°08.220′N 77°33.149′E	August–April (1996–2000)	0.15	132 (1997)	Grassland	*Vz*, *Dp*	1.57	250	200	5
2	South-east KNP (G-2) 27°08.540′N 77°32.938′E	October–November (1998 and 1999)	0.10	54 (1998)	Grassland	*Vz*, *Dp*	1.98	100	100	4.5
3	South-east KNP (G-3) 27°08.273′N 77°32.894′E	November–December (1998 and 1999)	0.10	40 (1998)	Grassland	*Vz*, *Dp*	1.38	100	100	5
4	South-east KNP (G-4) 27°08.260′N 77°33.422′E	December (1998 and 1999) January–April (1999 and 2000)	0.12	20 (1999) 50 (2000)	Grassland	*Vz*, *Dp*	1.61	150	100	5.5
5	South-east KNP (G-5) 27°07.954′N 77°32.599′E	November (1998 and 1999)	0.03	40 (1998)	Grassland	*Vz*, *Dp*	1.42	200	80	4
6	South-west KNP (Block K) 27°10.265′N 77°31.148′E	January (1996 and 1997)	0.09	33 (1997)	Wetland	*Ec*	0.60	150	50	0
7	North-east KNP (Block D) 27°09.953′N 77°31.684′E	January–March (1996 and 1997) December–March (1997–1998)	0.08	24 (1997) 35 (1997)	Wetland	*Ec*	0.55	250	80	0
8	North KNP (Block B) 27°10.394′N 77°31.258′E	March (1996 and 1997)	0.05	8 (1997)	Wetland	*Ec*	0.57	50	30	0
9	Kalyanpur village (5 km south-east of KNP) 27°06.374′N 77°30.523′E	August–September (1997 and 1998)	0.50	18 (1997)	Crop field	*Sb*, *Pt*	2.5	250	150	2
10	Barahe village (15 km south-west of KNP) 27°05.235′N 77°29.320′E	September–October (1998 and 1999)	0.06	30 (1998)	Sedgeland	*St*, *Ca*, *Es*	0.80	150	100	0.5
11	Kharera village (18 km south-west of KNP) 27°05.527′N 77°27.74′E	October–November (1998 and 1999)	0.15	35 (1998)	Grass (pasture)	*Pd*, *Da*, *Db*	0.5	150	30	1.5
12	Galau village (12 km south-west of KNP) 27°05.381′N 77°27.48′E	November–December (1998 and 1999)	0.39	25 (1998)	Ploughed field	Bare ground	0	150	300	2.5
13	Chak Undra village (14 km north-east of KNP) 27°11.157′N 77°37.731′E	March–April (1998 and 1999)	0.50	15 (1999)	Crop field	*Ta*	1.14	200	150	3
14	Kaproli village (7 km south-west of KNP) 27°08.316′N 77°29.934′E	February–April (1999 and 2000)	0.20	23 (2000)	Crop field	*Ta*	1.16	100	100	3
						Mean:	1.13	161	112	2.6

Principal vegetation: *Vz* = *Vetiveria zizanioides*; *Db* = *Desmostachya bipinnata*; *St* = *Scirpus tuberosus*; *Ca* = *Cyperus alopecuroides*; *Es* = *Echinochloa* sp.; *Pd* = *Paspalum distichum*; *Da* = *Dichanthium annulatum*; *Ec* = *Eichhornia crassipes*; *Sb* = *Sesbania bispinosa; Pt* = *Pennisetum typhoides*; *Ta* = *Triticum aestivum*.

Table 2. Comparison of communal roosts in grassland (N=5) with randomly chosen grassland sites (N=5). *P*-values are from Wilcoxon signed ranks tests.

Variable	Communal roosts	Non-roost sites	*P*
% cover of *Vetiveria zizanioides*	43.6	36.6	0.042
% cover of *Desmostachya bipinnata*	46.4	48.4	0.279
Mean height of *V. zizanioides* (cm)	156	140.2	0.893
Mean height of *D. bipinnata* (cm)	74.8	75.4	0.893
Distance to nearest road (m)	181.6	92.4	0.080
Distance to nearest tree (m)	61	35	0.461
Distance to nearest water body (m)	5.2	4.8	0.414
Number of trees	3.4	4.8	0.705

Table 3. Correlations between the maximum number of harriers recorded at communal roosts in grassland over the four years and various roost site variables.

Variable	Spearman's rank correlation coefficient	*P*
% cover of *Vetiveria zizanioides*	-0.200	0.747
% cover of *Desmostachya bipinnata*	-0.300	0.624
Mean height of *V. zizanioides* (cm)	0.700	0.188
Mean height of *D. bipinnata* (cm)	-0.800	0.104
Distance to nearest road (m)	-0.154	0.564
Distance to nearest tree (m)	0.975	0.005
Distance to nearest water body (m)	0.105	0.866
Number of trees	-0.821	0.089

typically surrounded roosting platforms, which consisted of short *Echinochloa colona* grass interspersed with *Ipomoea aquatica*. In pastures, roost sites were on platforms of *Paspalum distichum* in depressions among grasses (*Paspalum distichum*, *Echinochloa* sp., *Dichanthium annulatum* and *Desmostachya bipinnata*), sedges (*Cyperus rotundus*, *Scirpus tuberosus*) and herbs.

Travel and disturbance

Radio-tracking of four harriers showed that they usually travelled 3–12 km (n= 32 occasions) to reach their roost sites (Table 4), with a maximum distance of 40 km recorded for a juvenile in February 2000. The speed with which they travelled from roosts to foraging grounds was estimated to be 0.5 km/minute (n = six occasions for four individuals).

Table 4. Mean distance travelled by harriers from roost sites to foraging grounds in and around Keoladeo National Park during 1999–2000.

Individual	Mean (±SD) distance travelled (km)	N	Destination (from roost site in block G)	Date of leaving the Park
Juvenile 1	4.5 (±1.5)	4	Block F	4 February 2000
Juvenile 2	6.6 (±1.4)	4	Blocks E and F	13 February 2000
Juvenile 3	3.8 (±0.7)	4	Block F	11 January 2000
Adult female	8.7 (±3.5)	3	Block L, and from Kaproli to block N	2 February 2000

When disturbance from grass-cutting by local people became severe at grassland roosts (in December 1996, November 1997, December 1998 and November 1999), harriers shifted to roosts in wetlands, pastures, sedge, crops and ploughed fields. The adult female with a radio transmitter was recorded shifting her roost site from Block G to one in wheat fields at Kaproli village (7 km to the south-west) on 20 January 2000, apparently in response to disturbance by grass harvesting. Similarly, birds shifted from one wetland roost to another when disturbance occurred by people removing the exotic weed *Eichhornia crassipes* (in January 1997, March 1997 and December 1997), and from wetland roosts to drier roosts when the former became flooded (in September 1999).

DISCUSSION

Harriers spend considerable time in roost habitats, which are therefore crucial for their survival. Eurasian Marsh Harriers in the vicinity of KNP travelled fairly long distances from their foraging grounds to their roosts, suggesting that the roost sites provided significant benefits. Harriers roosted in large, open areas of uniform habitat, mainly natural grasslands, with *Desmostachya bipinnata* and *Vetiveria zizanioides*. Such grassland habitat may shelter roosting birds from cold winds (because of the dense high vegetation) and hence provide a favourable thermal environment (Cody 1985). Winter roost sites of American Robin *Turdus migratorius* have been shown to have 72% lower average wind velocity than unsheltered locations (Walsberg and King 1980). In addition, sheltered roosts may provide concealment from predators (Janes 1985), and predators may find it difficult to approach roosting harriers silently through tall grass.

The comparison of grassland roosts and non-roost sites suggests that Eurasian Marsh Harriers preferentially roost away from roads and trees. Great Horned Owl *Bubo virginianus* has been recorded preying on Hen Harriers *Circus cyaneus* at roosts (Weller *et al*. 1955). At KNP, the Dusky Eagle Owl *Bubo coromandus* is a potential predator of roosting harriers, and we observed antagonistic interactions on many occasions. Since the Dusky Eagle Owl is attracted to trees, this might explain the preference by the harriers for roosts away from trees. Roosting away from roads may reduce human disturbance and the risk of predation by terrestrial predators moving along them. At wetland roosts, harriers selected areas with dry water hyacinth, which probably helped to camouflage them from predators in the same way as Short-eared Owls *Asio flammeus* select dense, relatively light-coloured grassland roosts that match their plumage (Craighead and Craighead 1956).

Hirano *et al*. (1998) found that Eurasian Marsh Harriers in Central Japan roosted in patches of sparse reedbed dominated by short vegetation with a height of 40–60 cm and avoided taller reedbeds. They also preferred roost sites with undergrowth as night-time air temperature was significantly higher at such sites than in reedbeds without undergrowth. Watson and Dickson (1972) found that Hen Harriers in south-west Scotland roosted on the ground in the long heather (up to 1 m tall), creating trampled platforms, 0.5–1 m in diameter, of dead, bent, grey heather stalks, and noted that the harrier roosts were concentrated in an area of c.15–20 hectares. At Velavadar National Park, Gujarat, Akhtar (1998) and Clarke (1996) found that harriers roosted in grasslands dominated by *Dichanthium* sp. grass c.40–85 cm tall. Gurr (1968) described roosting habitat of the Australasian Harrier *C. approximans* in New Zealand. He found that all roosts were in swampy locations, along riverbeds, estuaries or adjacent to tarns in open country and occasionally they roosted in tall standing pasture crops such as lucerne. Each roost site was marked by about 0.8 m^2 of trampled vegetation, many white droppings, sometimes one or two casts, and occasionally white down. Most birds apparently perched on bent sedges which kept their feet out of the water, but at some sites the roosting birds' feet were probably in the water. Our findings accord with these previous studies.

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